February 13, 1902.

Sir WILLIAM HUGGINS, K.C.B., D.C.L., President, in the Chair.

A List of the Presents received was laid on the table, and thanks ordered for them.

The following Papers were read :—

I. "On the Sub-Mechanics of the Universe." By Professor OSBORNE REYNOLDS, F.R.S.

II. "On Chemical Statics and Dynamics under the Action of Light." By Dr. MEYER WILDERMAN. Communicated by Dr. LUDWIG MOND, F.R.S.

III. "Preliminary Note on a Method of Calculating Solubilities, Equilibrium Constants of Chemical Reactions, and Latent Heats of Vaporisation." By Dr. A. FINDLAY. Communicated by Professor RAMSAY, F.R.S.

IV. "The Refractive Indices of Fluorite, Quartz, and Calcite." By J. W. GIFFORD. Communicated by Professor S. P. THOMPSON, F.R.S.

"On the Sub-Mechanics of the Universe." By OSBORNE REYNOLDS, F.R.S.

Received February 3,—Read February 13, 1902.

(Abstract.)

Sections.

I. Introduction—Sketch of the results obtained and the steps secured.

II. The general equations of motion of any entity.

III. The general equations of motion in a purely mechanical medium, for mass, momentum, and energy.

IV. The equations of continuity for component systems of motion.

V. The mean and relative motions of a medium.

VI. The approximate equations of component systems of mean- and relative-motion.

VII. The general condition for the continuance of component systems of mean- and relative-motion.

VIII. The conducting properties of the absolutely rigid granule-ultimate atom or primordium.

IX. The probable ultimate distribution of the members of granular media, as the result of encounters, when there is no mean motion.

X. Extensions of the kinetic theory to include rates of conduction of momentum and energy through the grains, when the medium is in ultimate condition and under no mean strains.

XI. The redistribution of angular inequalities in the relative system.

XII. The linear dispersion of mass, and of momentum and energy of relative motion by convection.

XIII. The exchanges between the mean and relative systems.

XIV. The conservation of inequalities in the mean mass and their motions about local centres.

XV. The determination (1) of the relative quantities α'', λ'', σ, and G which define the state of the medium by the results of experience; (2) the general integration of the equation.

1. In this paper it is shown that there is one, and only one, conceivable purely mechanical system capable of accounting for all the physical evidence, as we know it, in the universe.

The system is neither more nor less than an arrangement of indefinite extent of uniform spherical grains, generally in normal piling, so close that the grains cannot change their neighbours, although continually in relative motion with each other, the grains being of changeless shape and size, thus constituting, to a first approximation, an elastic medium, with six axes of elasticity symmetrically placed.

The diameter of a grain, in C.G.S. units, is

$$5{\cdot}534 \times 10^{-18} = \sigma.$$

The mean relative velocities of the grains are

$$6{\cdot}777 \times 10 = \alpha''.$$

The mean path of the grains

$$8{\cdot}612 \times 10^{-28} = \lambda''.$$

These three quantities completely define the state of the medium in spaces where the piling is normal; they also define the mean density of the medium as compared with the density of water as

$$10^4 = 22\Omega.$$

The mean pressure in the medium equal in all directions is

$$1{\cdot}172 \times 10^{14} = p.$$

The coefficient of the transverse elasticity resulting from the gearing of the grains where the piling is normal is

$$9{\cdot}030 \times 10^{30} = n.$$

The rate of propagation of the transverse wave is

$$3{\cdot}000 \times 10^{10} = \tau \;.\; (n/\rho).$$

The rate of propagation of the normal wave is

$$7{\cdot}161 \times 10^{10} = 2{\cdot}387 \times \tau.$$

The rate of degradation of the transverse waves, *i.e.*, the dissipation resulting from the angular redistribution of the energy or viscosity is

$$5{\cdot}603 \times 10^{-16} = t_t,$$

or such as would require 56,000,000 years to reduce the total energy in the wave in the ratio $1/e^2$, or to one-eighth, thus accounting, by mechanical considerations, for the blackness of the sky on a clear dark night, while the degradation of the normal wave, *i.e.*, the dissipation resulting from the linear redistribution of energy is such that the initial energy would be reduced to one-eighth in the $3{\cdot}923 \times 10^{-6}$th part of a second, or before it had traversed 2200 metres; and thus would account, by mechanical considerations, for the absence of any physical evidence of normal waves, except such evidence as might be obtained within some thousand metres of the origin of the waves, as in the case of Röntgen rays.

2. In spaces in which there are local unequal inequalities in the medium about local centres owing to the absence or presence of a number of grains in deficiency or excess of the number necessary to render the piling normal, such local inequalities are permanent, and are attended with inward or outward strains, as the case may be, extending indefinitely throughout the medium, causing dilatation equal everywhere to the strains, but of opposite sign, *i.e.*, dilatation equal to the volume of the grains, the presence or absence of which causes the inequality.

When the arrangement of the grains about the centres is that of a nucleus of grains in normal piling, on which the grains in the strained normal piling rest, the nucleus in normal piling cannot gear with the grains outside in strained normal piling; so that there is a singular surface of misfit between the nucleus and the grains in strained normal piling. Such singular surfaces are surfaces of weakness, and may be surfaces of freedom, or surfaces of limited stability with the neighbouring grains.

These singular surfaces, when their limited stability is overcome, are free to maintain their motion through the medium, by a process of propagation in any direction, the number of grains entering the surface on the one side being exactly the same as the number leaving on the other side, so that when the inequalities are the result of the absence of grains, they correspond to the molecules of matter.

If the singular surface of a negative inequality is propagating through a medium which is at rest, the grains forming the nucleus will have no motion, whatever may be the motion of the singular surface. But the strained normal piling which surrounds the singular surface and moves by propagation with the singular surface, being of less density than the mean density of the medium, represents a displacement of the negative mass of the inequality, *i.e.*, of the grains absent,

and in whatever new direction the singular surface is propagated, the motion of the medium outside is such as represents equal and opposite momentum, as when a bubble is rising in a glass of water.

In exactly the same way, for inequalities resulting from an excess of grains, the momentum resulting from the displacement of the medium would be positive.

The principal stresses in the medium outside the singular surface of a negative inequality are to a first approximation two equal tangential pressures equal in all directions :—

$$p_t = \frac{6}{5} p;$$

and a normal pressure :—

$$p_n = \frac{3}{5} p;$$

the mean of these pressures being everywhere the mean pressure of the medium equal in all directions.

Efforts, proportional to the inverse square of the distance, to cause two negative inequalities to approach from a finite distance, are the result of those components of the dilatation (taken to a first approximation) which are caused by the variation of those components of the inward strains which cause curvature in the normal piling of the medium.

The other components of the strain, being parallel distortions, which satisfy the condition of geometrical similarity, do not affect the efforts. If the grains were indefinitely small there would be no effort; thus the diameter of a grain is the parameter of the effort, and, multiplying this diameter by the curvature of the medium and again by the mean pressure of the medium, the product measures the intensity of the effort.

The dilatation diminishes as the centres of the negative inequalities approach, and work is done by the pressure in the medium outside the singular surfaces to bring the negative inequalities together.

The efforts to cause the negative inequalities to approach correspond exactly to the gravitation, if matter represents negative mass.

Taking the mean density of the earth as $-5{\cdot}67$ as compared with water (-1),

The reciprocal of the density of the medium being	$0{\cdot}10^{-4}$,
The mean pressure of the medium	$1{\cdot}172 \times 10^{14}$,
σ the diameter of a grain	$5{\cdot}534 \times 10^{-18}$,
The mean radius of the earth	$6{\cdot}3709 \times 10^{8}$,

the effort to cause approach between the earth and a unit of matter on the earth's surface (-1) is the product of these quantities multiplied by $4\pi/3$, or:

$$p\sigma \times 10^{-4} \times \frac{4}{3}\pi \times 5{\cdot}67 \times 6{\cdot}3709 \times 10^{8} = 9{\cdot}81 \times 10^{2}.$$

The inversion is thus complete; matter is the absence of mass, and the effort to bring the negative inequalities together is also an effort on the mass to recede. And since the actions are those of positive pressure there is no attraction involved; the efforts being the result of the virtual diminution of the pressure inwards.

3. If instead of the negative inequalities as in the last article the inequalities are positive the efforts are reversed, tending to separate the inequalities, and the analysis would be the same, except that the curvature would be negative. And it is important to notice that if such positive inequalities exist the fact that they repel each other, *i.e.*, that they would tend to scatter through space, together with the evidence that the number of inequalities, either positive or negative, occupy an indefinitely small space as compared with the total volume of the medium, places any importance such positive inequalities might have on a footing of indefinitely less importance than that of the negative inequalities which are caused to accumulate by gravitation; and thus we have an explanation of any lack of evidence of any positive inequalities—even if such exist.

4. Besides the positive and negative inequalities, there is another inequality which may easily be conceived—and that is of fundamental importance. Whatever may be the cause it is possible to conceive that a number of grains may be removed from one position in the medium to another, the medium being otherwise uniform; thus instituting a complex inequality as between two inequalities, one positive and the other negative; the number of grains in excess in the one being exactly the same as the number of grains absent in the other.

The complex inequalities differ fundamentally from the gravitating inequalities, inasmuch as the former involve an absolute displacement of mass, while the latter have no effect on the mean position of the mass in the medium, and in respect of involving absolute displacement of mass the complex inequality corresponds with electricity.

Apart from the displacement of mass, the complex inequalities differ from the gravitating inequalities. In the complex inequalities the parameter of the dilatation is not the diameter of a grain, but one-half the linear dimension of the volume occupied by the grains displaced, taken as spherical.

The effort to revert in the case of the complex inequality is the product of the pressure multiplied by the product of the volume of the positive and negative inequalities, and again by the parameter, r_0. This is expressed when the positive and negative inequalities are at finite distances apart by

$$p\left(\frac{4\pi}{3}\right)^3 r_0^{\,7} = -\mathrm{R},$$

R being essentially negative, and the dimensions of the effort $(-\mathrm{R})$ are mlt^{-2}, which express an effort to the displacement of mass.

The complex inequality which corresponds to the separation of the positive and negative inequalities is one displacement, not two. This fact admits of no question, and might have been recognised long ago had it not been for the general assumption that positive electricity repels positive electricity, the fact being that the apparent repulsion of the positive electricities is the result of their respective efforts to approach their respective negative inequalities. By the assumption it became apparently possible to express the potential v and the electricity q as rational quantities, while, as it now appears, the potential v and the electricity q are respectively

$$-(-e^2)^{\frac{1}{2}}.\frac{1}{r} \quad \text{and} \quad (-e^2)^{\frac{1}{2}},$$

which are both irrational. Their product being the rational quantity

$$e^2/r,$$

which differentiated with respect to the distance is

$$-e^2/r^2 = \mathrm{R}.$$

And the mechanical explanation of these is

$$-\left[-p\left(\frac{4\pi}{3}\right)^2.r_0^7\right]^{\frac{1}{2}}.\frac{1}{r}=v, \qquad \left[-p\left(\frac{4\pi}{3}\right)^2.r_0^7\right]^{\frac{1}{2}}=q,$$

and for the effort to revert we have—

$$p\left(\frac{4\pi}{3}\right)^2.\frac{r_0^7}{r^2} = -\mathrm{R}.$$

Then for the electrostatic units we have, since $r = 1$, and $\mathrm{R} = -1$,

$$p\left(\frac{4\pi}{3}\right)^2 r_0^7 = 1,$$

and from the known value of p, the number of grains displaced through unit distance necessary to cause the unit effort is

$$1{\cdot}615 \times 10^{45},$$

and $r_0 = 6{\cdot}493 \times 10^{-3}$, from which we have the ratio of the effort to reinstate the normal piling, to the effort of gravitation, from the same number of grains absent in each inequality as are displaced in the complex inequality, the distances being the same

$$1{\cdot}2 \times 10^{15};$$

so that the effort of attraction between two inequalities, the grains absent about each of which are the same as the grains displaced in

instituting the complex inequality, is eighty-one thousand billions less than that of the electric effort.

5. Cohesion between the singular surfaces of the negative inequalities results from the terms which were not taken into account in the first approximation, which corresponds to gravitation. These secondary terms involve the inverse distance to the sixth power, and have therefore a very short range, and so correspond to efforts of cohesion of the singular surfaces as well as surface tensions, having no effect when the singular surfaces, or molecules, are separated by a distance very small compared with the diameter of the singular surface.

6. Transverse undulations in the medium corresponding to the waves of light are instituted by the disruptive reversion of the complex inequalities. The recoil sets up a vibration which is exhausted in initiating light.

7. Thus far the sketch of the results has included only those for which there exists sufficient evidence to admit of definite quantitative analysis. Nevertheless, these quantitative results show that the granular medium, as already defined, accounts by purely mechanical considerations for the evidence, and affords the only purely mechanical explanation possible. If then the substructure of the universe is mechanical, all the evidence not already adduced is such as may be accounted for by an extension of the analysis. And this is found to be the case.

The results of the further analysis afford proof—

Of the existence of coincidence between the periods of vibration of the molecules and the periods of the waves;

That dissociation of the compound molecules proves the previous state to have been one of limited stability;

That the reassociations of compound molecules result from the reversion of complex inequalities;

Of the absorption of the energy of light by inequalities;

That negative inequalities affect the waves passing through;

That refraction is caused by the vibration of inequalities having the same periods as the waves;

That dispersion results from the greater number of coincidences as the waves get shorter;

That the polarisation by reflection is caused only by that component of the transverse motion in the medium which is in the plane of incidence and results from the passage of the light from a space without, or with few, inequalities, through a surface into a space in which there are more inequalities;

That the metallic reflection results from the relative smallness of the dimensions of the molecules compared with the length of the wave and the closeness of their piling when the waves pass from

a space without inequalities across the surface beyond which the inequalities are in closest order;

That the aberration of light results from the absence of any appreciable resistance to the motion of the medium when passing through matter.

8. It may be somewhat out of the usual course to describe the results of a research before any account has been given of the method by which these results have been obtained; but in this case the foregoing sketch of the purely mechanical explanation of the physical evidence in the universe by the granular medium has seemed the only introduction possible. And even so it is not with any idea that this introduction can afford any preliminary insight as to the methods by which these results have been obtained.

Certain steps, as it now appears, were taken for objects quite apart from any idea that they would be steps towards the mechanical solution of the problem of the universe. The first of these steps was taken with the object of finding a mechanical explanation of the sudden change in the rate of flow of the gas in the tubes of a boiler when the velocity reached a certain limit; perhaps this would be better described as a step towards a step.*

The second step was the discovery of the thermal transpiration of gas together with the analytical proof of the dimensional properties of matter.†

The third step was the discovery of the criterion of the two manners of motion of fluids,‡ and it was only on taking the fourth step, namely, the study of the action of sand, which revealed dilatancy as the ruling property of all granular media§ which directed attention to the possibility of a mechanical explanation of gravitation. In spite of the apparent possibility all attempts to effect the necessary analysis failed at the time.

There was, however, a fifth step: the effecting of the analysis for viscous fluids, and the determination of the criterion,|| which led to the recognition of the possibility of the analytical separation of the general motion of a fluid into mean varying motion, displacing momentum, and relative motion without mean momentum; and this suggested the possibility that the medium of space might be granular, the grains being in relative motion, and at the same time being subject to varying mean motion. And this has proved to be the case.

At the same time it became evident that it was not to be attacked by any method short of the general equations of a conservative system

* 'Manchester Lit. and Phil. Soc.,' 1874–5, p. 7.

† 'Phil. Trans.,' 1879.

‡ 'Phil. Trans.,' 1883.

§ 'Phil. Mag.,' 1885.

|| 'Phil. Trans.,' 1895.

starting from the very first principles; and it is from such study that this purely mechanical account of the physical evidence has been obtained.

"Micro-crystalline Structure of Platinum." By THOMAS ANDREWS, F.R.S., F.C.S. Received October 26,—Read November 28, 1901.

[PLATE 6.]

The crystalline structure of platinum does not appear to have been studied, although it forms an interesting subject for investigation.

A small ingot of pure platinum was obtained for the experiments. A section was cut therefrom and machined to $\frac{5}{16}$ inch square and $\frac{1}{10}$ inch in thickness. The section was then carefully polished and etched in aqua regia of the following strength:—

4 parts of hydrochloric acid (sp. gr. 1·2).
1 part of nitric acid (sp. gr. 1·42).

When the polished micro-section was immersed in the aqua-regia solution in the cold, no solvent action occurred, although the metal was exposed for a considerable time in the reagent.

The temperature of the etching solution was then gradually raised to boiling point, at which it was maintained for 15 seconds, but it had apparently no visible effect on the platinum, as ascertained by microscopical examination, after having previously washed the section with water and pure alcohol.

The etching process was repeated and the metal again exposed for a further period of 30 seconds, but after microscopical examination of the surface of the metal it was found that even this exposure had not satisfactorily developed a structure in the metal.

The etching process was again repeated and the micro-section exposed for another 15 seconds to the boiling aqua-regia solution above described. This developed a better crystalline structure, though not a thoroughly satisfactory one. The same micro-section of platinum was therefore again exposed to the action of boiling aqua regia for a further period of 45 seconds, resulting in the development of a beautiful crystalline structure which manifested not only the large or primary crystal grains but also the secondary or very minute crystalline development which is illustrated on Plate 6.

Fig. 1 shows the micro-crystalline structure of pure platinum as seen in transverse section by oblique illumination at a magnification of 50 diameters.

Fig. 2 shows, at a magnification of 120 diameters, the crystalline structure as indicated in transverse section by the direct or vertical method of illumination. This micro-section illustrates the general